# BRL



REPORT NO. 54

# SECOND PARTIAL REPORT ON RESEARCH ON ROCKET PROPULSION OF PROJECTILES

by

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July 1936



U.S. ARMY ABERDEEN RESEARCH AND DEVELOPMENT CENTER
BALLISTIC RESEARCH LABORATORY
ABERDEEN PROVING GROUND, MARYLAND



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Report No. 54

July 29, 1936

# 2nd Partial Report on Research on Rocket Propulsion of Projectiles.

Research Project RZ - 101.
Authority APG 121.2/12196.

## Abstract.

This report covers the experiments in static test apparatus of the burning of gasoline with oxygen or nitrous oxide to attempt to determine if fuels of this nature and the mechanisms for using them appear to be practical for use in a rocket propelled projectile. While fairly satisfactory control of burning was obtained, the high heat resulting and the complication of the means necessary for using a liquid fuel and gas indicate that this means of propulsion is not practical in small projectiles, though possibly in those of large size it might be successfully used.

## Report on Experiments with Gasoline and Oxygen as Fuel for Rocket Projectiles.

Previous Reports:

1st Partial Report on Research on Rocket Propulsion of Projectiles O.P. 5191 A.P.G., Md., April 7, 1933. O.O. 475.71/859. A.P.G. 475.71/2. Book 72.

An Investigation of Erosion in Orifices caused by Powder Gases at High Temperature and Velocity. Watertown Arsenal May 7, 1934. Report No. 731/4.

Report on Rocket Propulsion of Projectiles.
Research Project RZ-101. A.P.G. May 31, 1935.
Report #7.

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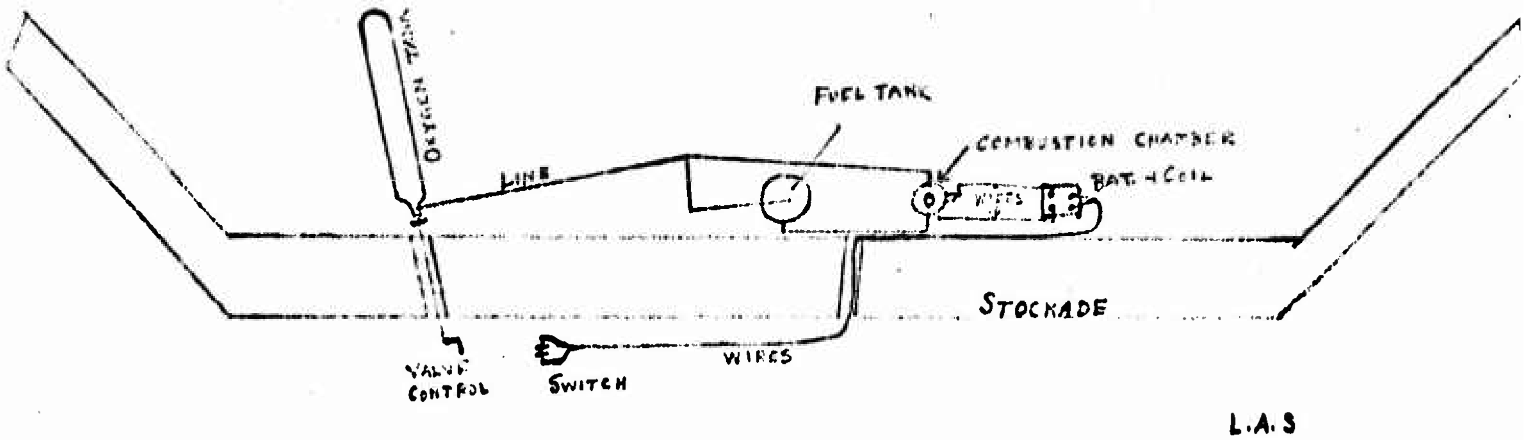
FIG. 1.


OXYGEN TANK
FUEL TANK
COMBUSTION CHAMBER
LINE
BAT. & COIL
STOCKADE
VALVE CONTROL
SWITCH
WIRES
L.A.S

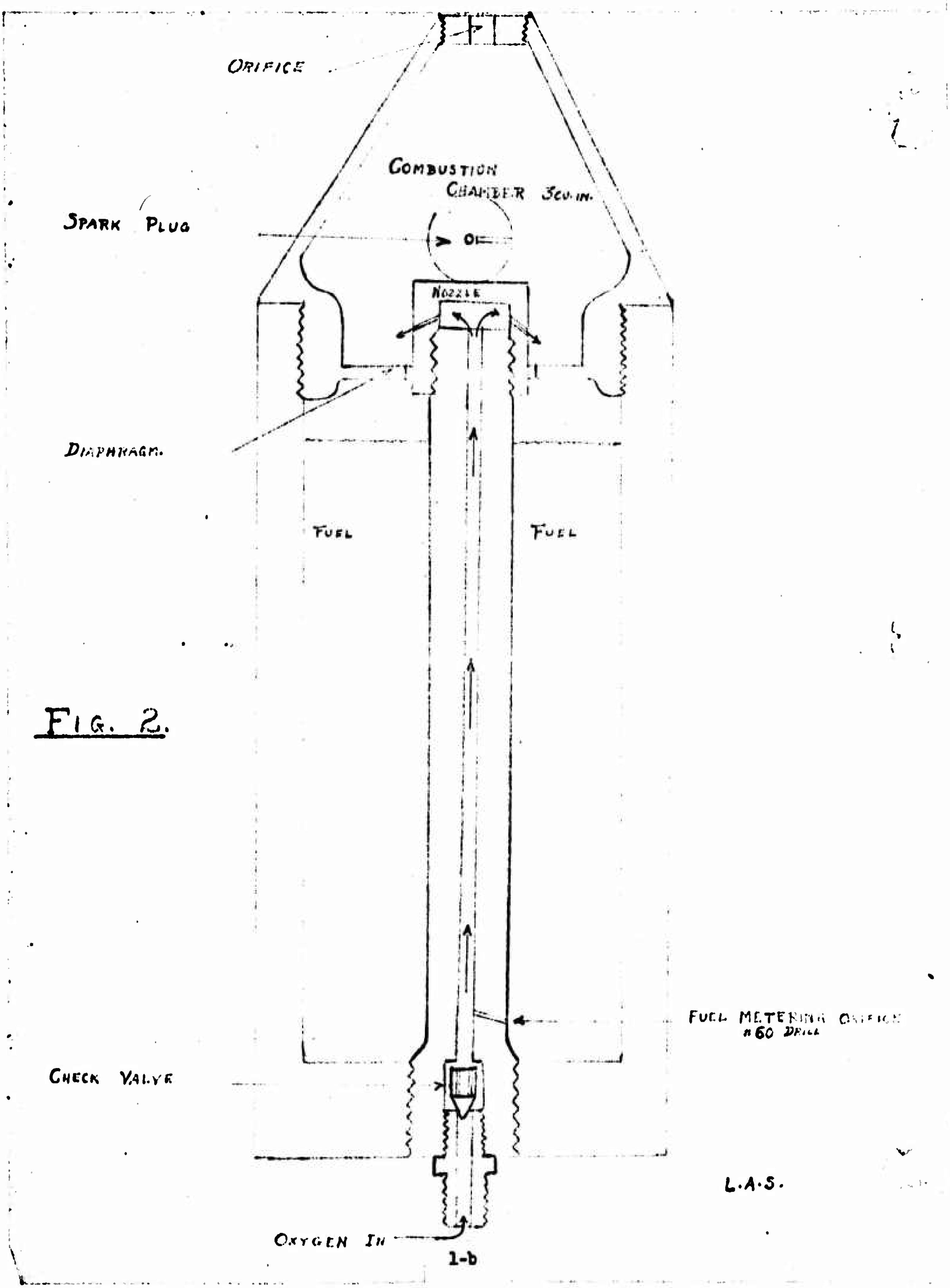

ORIFICE
COMBUSTION CHAMBER 3cu. in.
SPARK PLUG
NOZZLE
DIAPHRAGM.
FUEL
FUEL
FUEL METERING ORIFICE #60 DRILL
CHECK VALVE
OXYGEN IN

FIG. 2.

L.A.S.

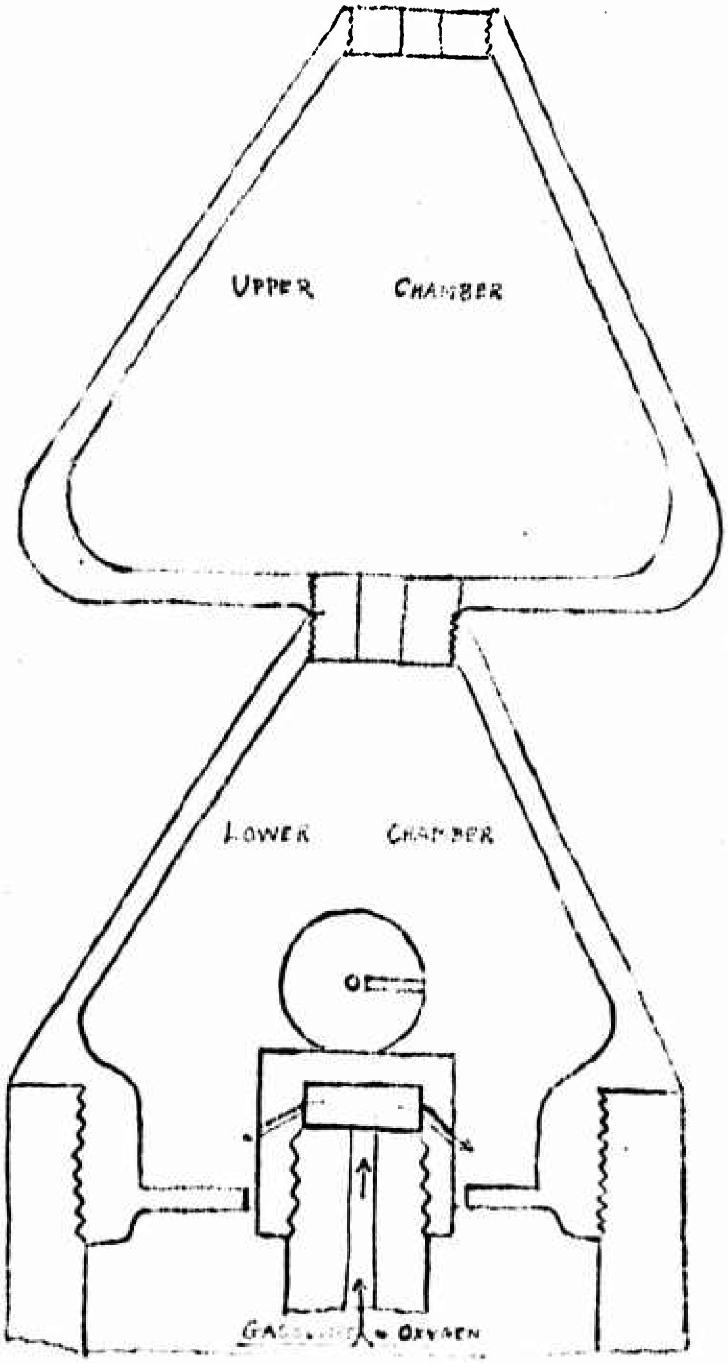
## First Test Apparatus.

Fig. 1 shows diagramatically the general arrangement of apparatus in a stockade. The sketch (Fig. 2) illustrates diagramatically the set-up of the first apparatus tried. Nitrous oxide was used as the oxygen furnishing agent because its critical pressure and temperature are such that it can be used in liquid state at any temperatures likely to be met, because it is easily obtainable commercially and because it was expected that the presence of the nitrogen would to some extent aid in control of the burning and reduce the resulting heat. This was found to be the case. Considerable trouble was experienced in controlling the amount of liquid entering the gas stream however. As shown by the sketch the fuel was sucked into the feed tube thru small orifices by the flow of the gas across the orifices, control being obtained by plugging the holes (which as originally drilled proved too large,) and drilling fewer and smaller holes, finally coming to one hole drilled with a #60 drill. No reducing valve was used on the gas cylinder, the pressure being used between the limits of 1600 to 300#/sq. in., as the gas was consumed. Very little difference in burning time of one measure of fuel was evident with a full gas cylinder (1600#/sq. in. approx.) and one which had been used till the pressure was only about 300#/sq. in. This possibly can be accounted for primarily by the action of the check valve shown in the sketch. This valve was designed to cut off back pressure resulting from the explosion from the feed tube and to reduce the possibility of forcing any gasoline vapor into the gas cylinder. The action of the valve was such that the charge burned with a series of explosions rather than continuously. When the nitrous oxide was first turned on a mixture of gasoline and $N_2O$ were sprayed into the combustion chamber where ignition took place by firing a spark plug. The first explosion momentarily caused considerable increase in pressure and as can be seen, acted directly on the surface of the liquid fuel, burning of the explosive mixture taking place below as well as above the diaphragm. The pressure in the combustion chamber dropped rapidly as the products of combustion were exhausted thru the orifice, but the pressure below the diaphragm dropped more slowly due to the small clearance between the nozzle post and the diaphragm, this momentarily unbalanced the pressure on the two sides of the diaphragm and caused the liquid fuel to be forced up thru the nozzle post, entering the latter thru the fuel metering orifice and out the exhaust orifice, the pressure during this action apparently being sufficient to keep the check valve closed. This was evidenced by the fact that each explosion was followed by a visible emission of fuel vapor which was not burning, from the exhaust orifice. When the pressure dropped sufficiently to permit the check valve to open again, with the resumption of flow of the

N2O another explosion took place in the combustion chamber this action being automatic after the first second or two, ignition then taking place without any further action of the spark plug. The cycle was: an explosion accompanied by a point of brilliant white flame from the orifice, then the ejection of a plume of vaporized gasoline then another explosion, etc.

It was apparent that most of the fuel was being forced out unburned and tho the explosions took place very rapidly (about 450/min. as estimated from a machine gun which was firing nearby at that rate at the same time the test apparatus was firing) the fuel, about 1/2 pint, lasted only about 4-5 sec.

FIG 3.




L.A.S.

In an effort to correct this a modification as shown in Fig. 3 was made. The functioning here appeared about as before except that the wastage of fuel was reduced somewhat, the rapidity of explosions materially increased and the heat also, as evidenced by the rapid melting away of the orifice which in the first case, had given no trouble. Burning time here for the same amount of fuel was about 10-12 sec. at which time, after several previous trials of shorter duration, the bottom chamber melted thru on one side.

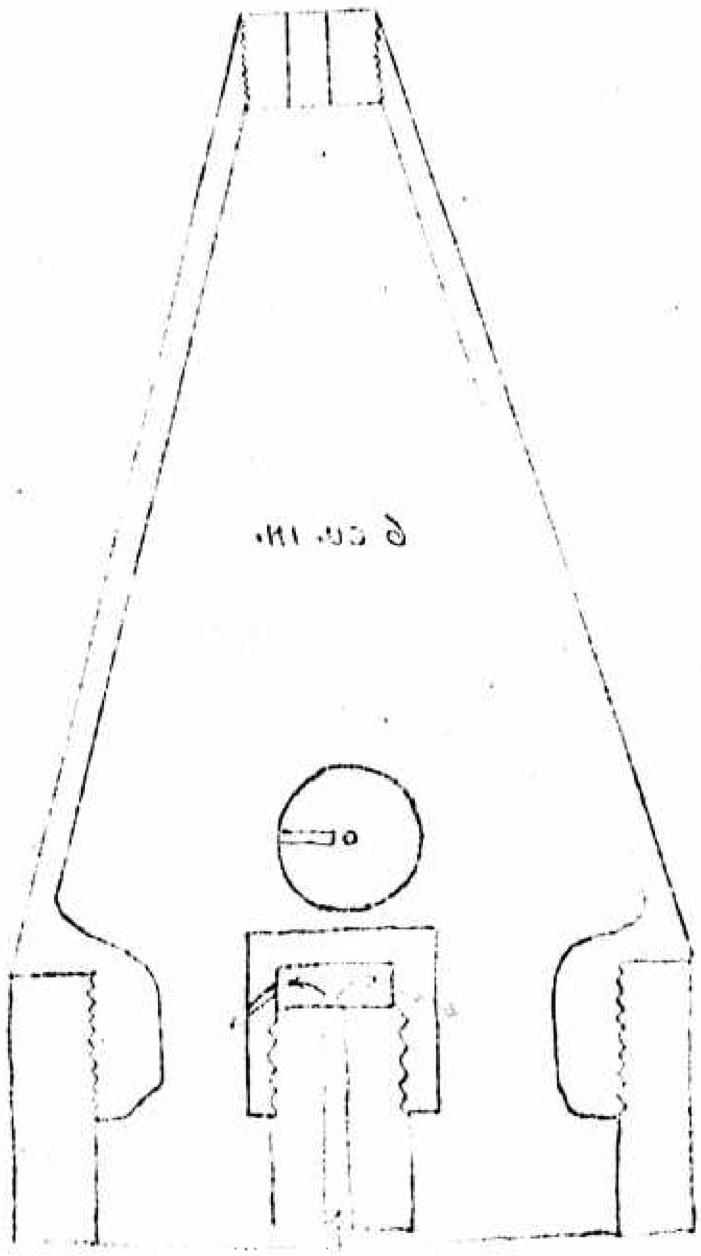
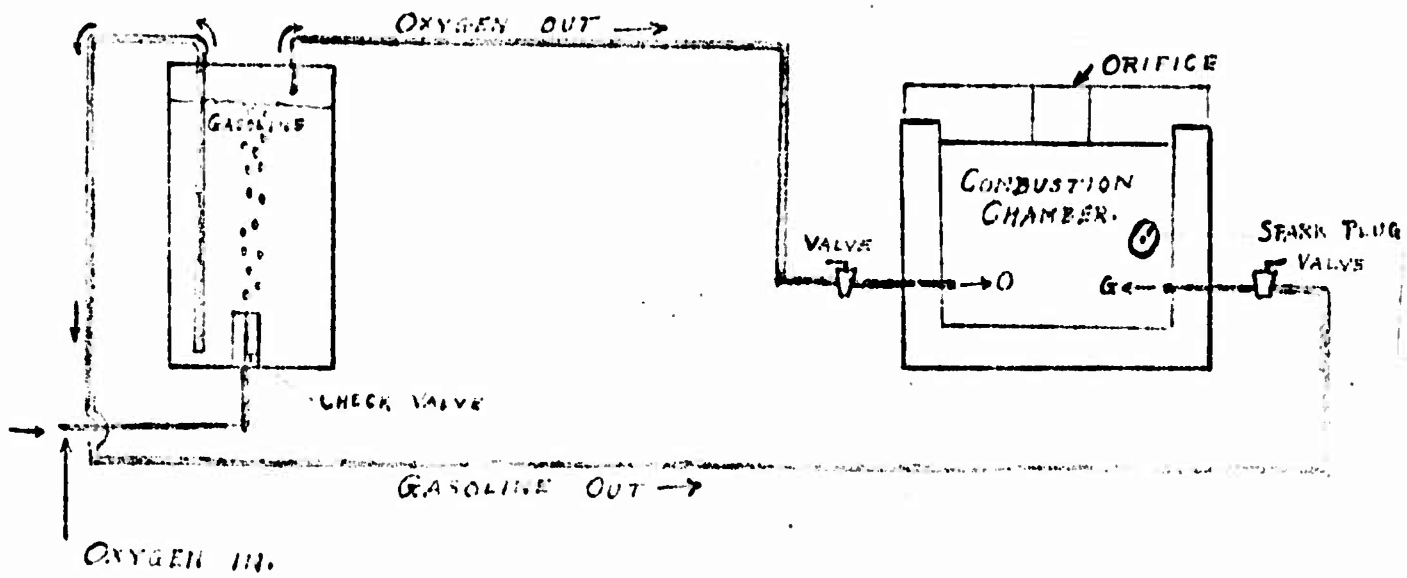



Fig. 4.

Fig. 4 shows the same test cylinder with a larger combustion chamber of about 6 cu. in. as compared with the approximately 3 cu. in. of the small ones and the elimination of the diaphragm. Burning time was materially increased and burning was continuous but when N2O was fed in rapidly by opening the tank valve considerably in order to get a high rate of efflux of gases thru the exhaust orifice, the whole top of the apparatus reached a cherry red in about 14 sec. and the gas was cut off so as not to melt the cylinder, the orifice body having practically disappeared in this time.



OXYGEN OUT →
ORIFICE
GASOLINE
COMBUSTION CHAMBER.
VALVE
SPARK PLUG
VALVE
O
G
CHECK VALVE
GASOLINE OUT →
OXYGEN IN.


FIG. 5.

L.A.S.

The apparatus was now completely redesigned as shown in Fig. 5 which was unsuccessful due to the fact that every time the charge was ignited in the chamber an explosion took place in the oxygen line since the oxygen was mixed with considerable gasoline vapor. Here welding oxygen was used instead of $N_2O$.

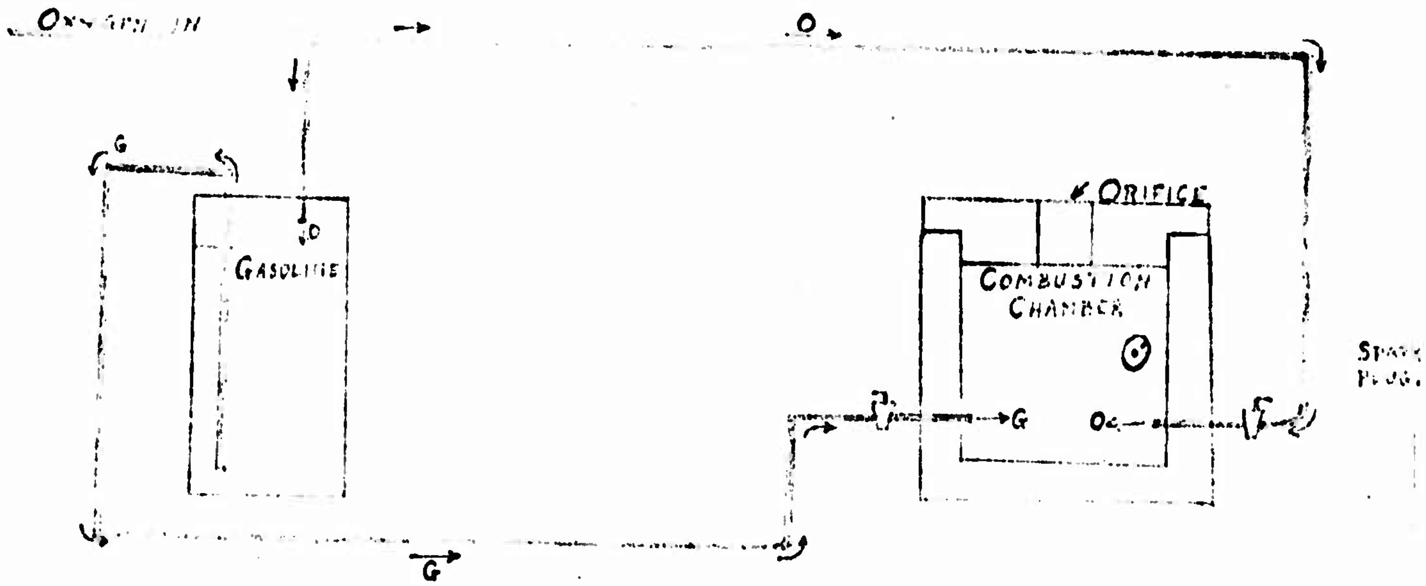



FIG. 6.

L.A.S.

The apparatus was then designed as shown in Fig. 6. This worked well, gave good control of combustion, an oxidizing or reducing flame being obtainable at will. However when the fuel level got below the mouth of the fuel feed tube an explosion took place in the fuel tank, wrecking it and the lines. The apparatus was rebuilt in exactly the same way except that the end of the fuel tube was closed and several #50 holes drilled close to the lower end of this tube. A 1/4 inch layer of finely ground cork was floated on the surface of the fuel, acting to close the holes when the fuel was almost exhausted, keeping any oxygen from entering the fuel line, thereby preventing any flash back thru this tube into the fuel tank. Burning quietly stopped when all holes were plugged.

Having an apparatus which appeared to burn the fuel as desired the problem of getting an orifice that would not enlarge appreciably under the action of the exhaust gases had to be met. Once ignition was started with the spark plug it continued until the fuel was exhausted, however with a steel orifice body the orifice enlarged so rapidly that in 4-5 sec. the pressure in the chamber was greatly reduced and the burning was more gentle, much like that of a welding torch. The fuel tank held approximately 5 oz. of gasoline which was sufficient to burn about 45 sec. with an oxygen pressure of about 1600#/sq. in., the oxygen tank valve being opened one full turn.

Three materials were tried as orifice lines which stood up quite well. The first material tried was a piece of carbon stick as used in the 60" searchlight. A 1/4 inch diameter hole was drilled thru this and a slightly reducing flame used. Enlargement in 40-45 sec. was to an orifice diameter of about 3/8". Boron carbide, pressed into a steel sleeve and having a 1/4 inch orifice showed no appreciable enlargement in 40-45 sec. tho it was full of minute cracks. Tungsten-nickel alloy (87% tungsten - 13% nickel) showed no appreciable enlargement in 40-45 sec.

While no attempt was made, due to lack of time (since these experiments were carried out entirely outside of regular duties) to measure the reaction forces acting on the combustion chamber, there was evidence such as the impression of the base of this chamber in the wood block on which it was placed, that they were appreciable. Since the complication of the apparatus was such that it appeared not suitable to the purpose, further work along this line was dropped.

Work is continuing slowly on the problem, attempting again to suitably use some kind of powder as a fuel.

<u>Note</u>: At no time during this work did a spontaneous explosion take place due to the mixture of gasoline, either as a liquid or a vapor, with gaseous oxygen unless the mixture were run into a heated chamber.

Conclusions:

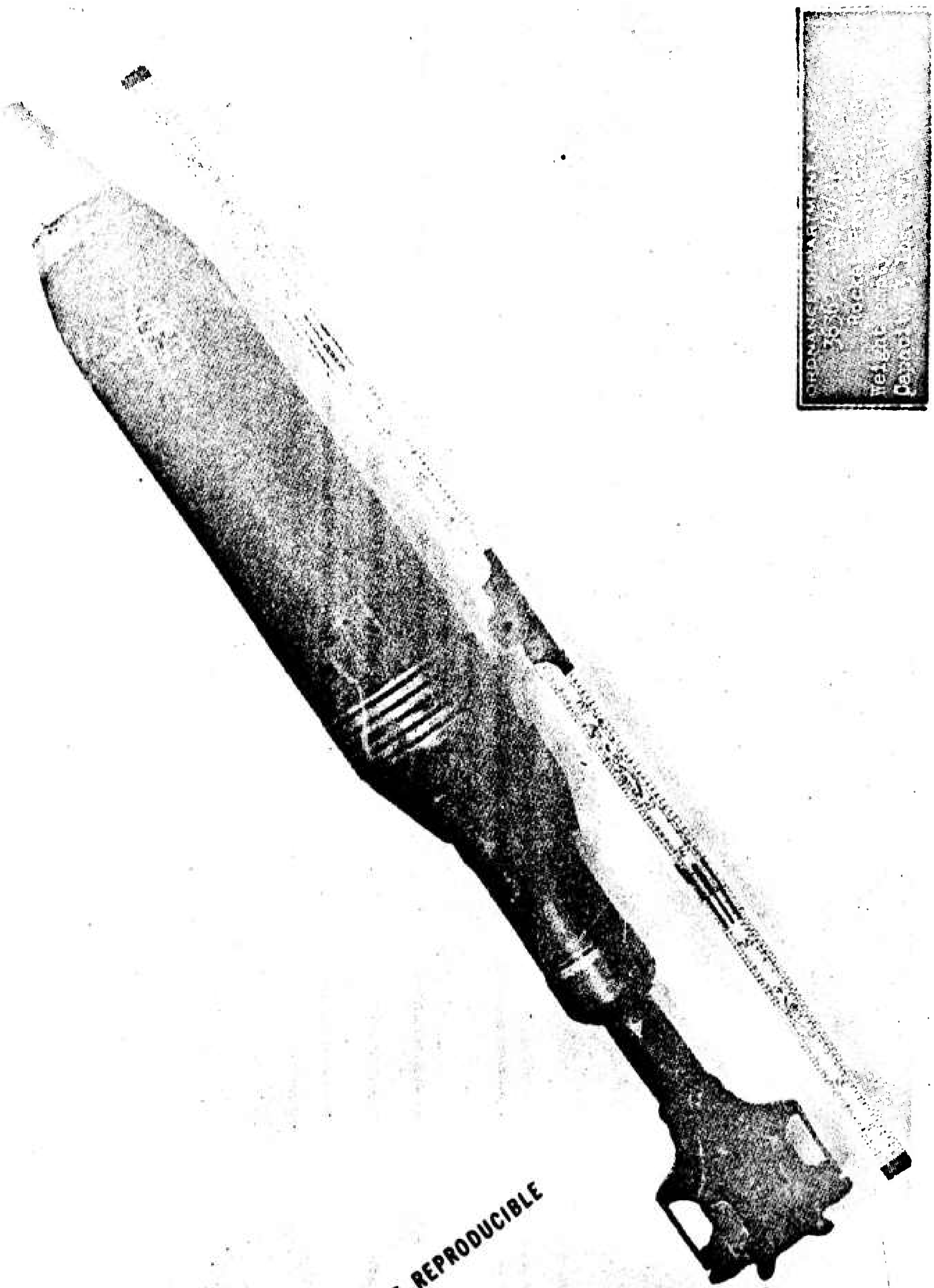
1. That gasoline and oxygen can be made to burn satisfactorily as a rocket fuel without the use of an auxiliary tank of compressed nitrogen or a pump to force the fuel into the combustion chamber.

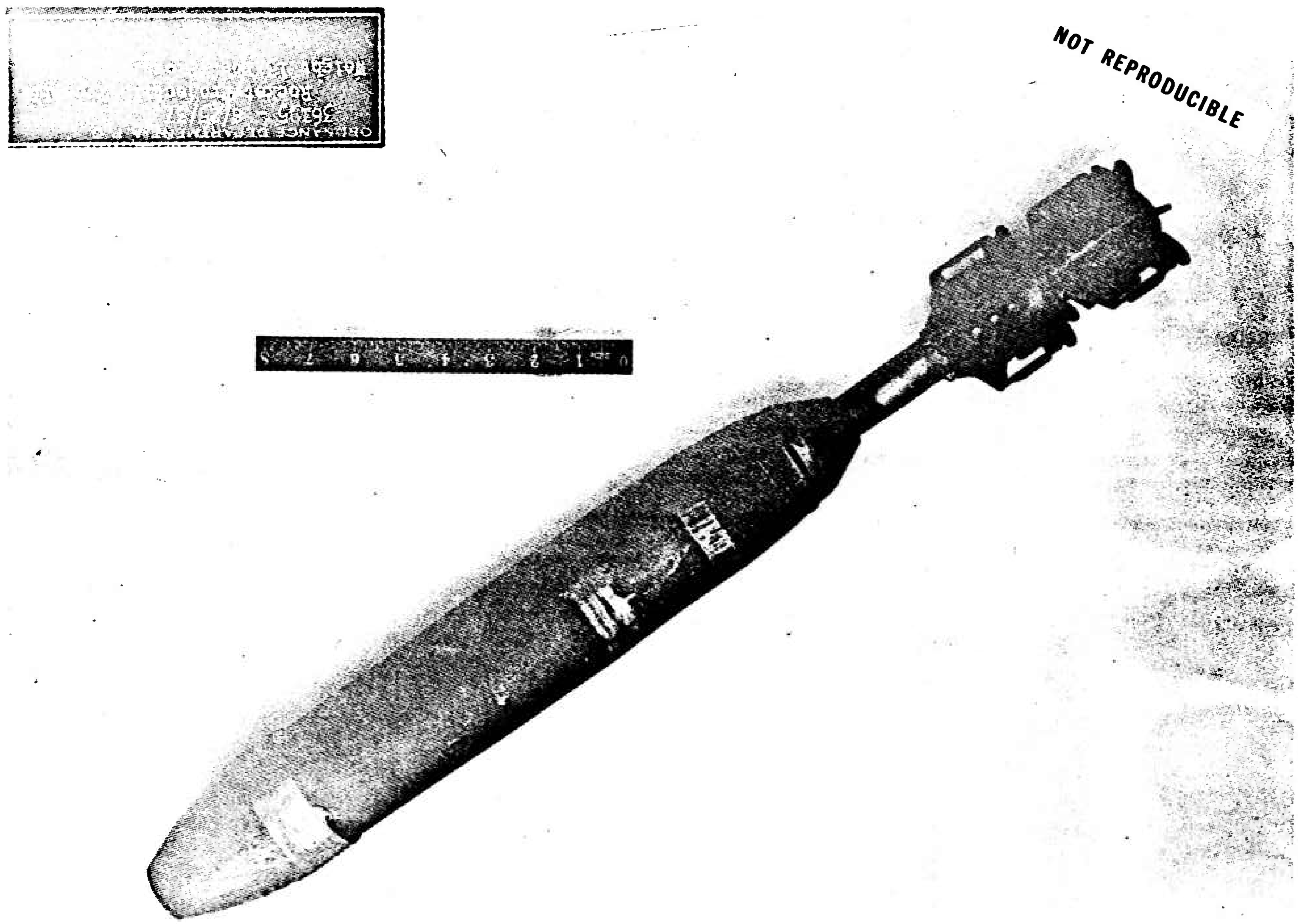
2. That the apparatus required, as determined from the work done, is too complicated for use as a source of power for propulsion of rocket projectiles unless possibly they be large ones.

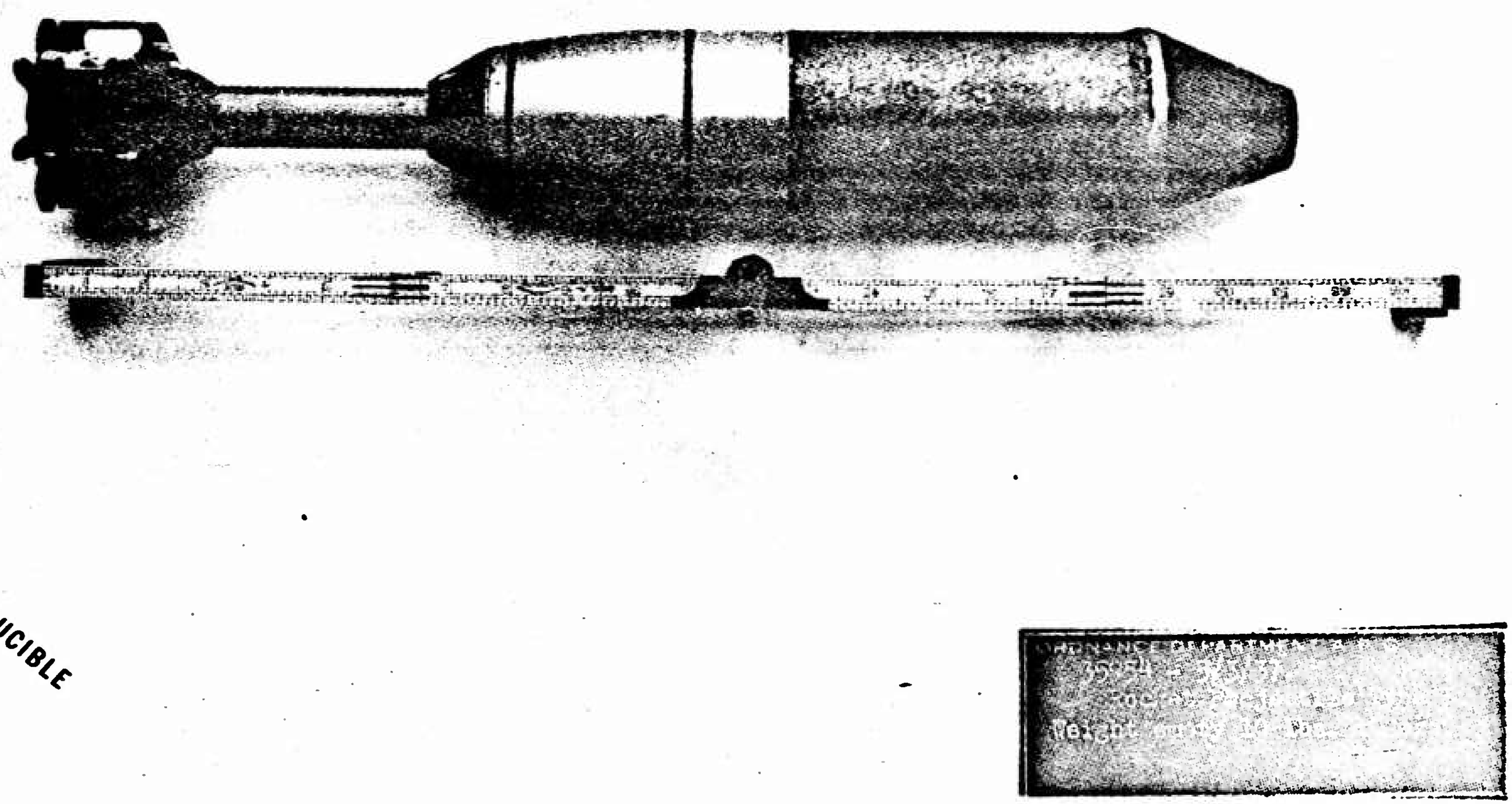
3. That for this purpose a solid fuel having proper burning characteristics and as much energy as possible is more practical of application than a liquid fuel and gaseous oxidizing agent.

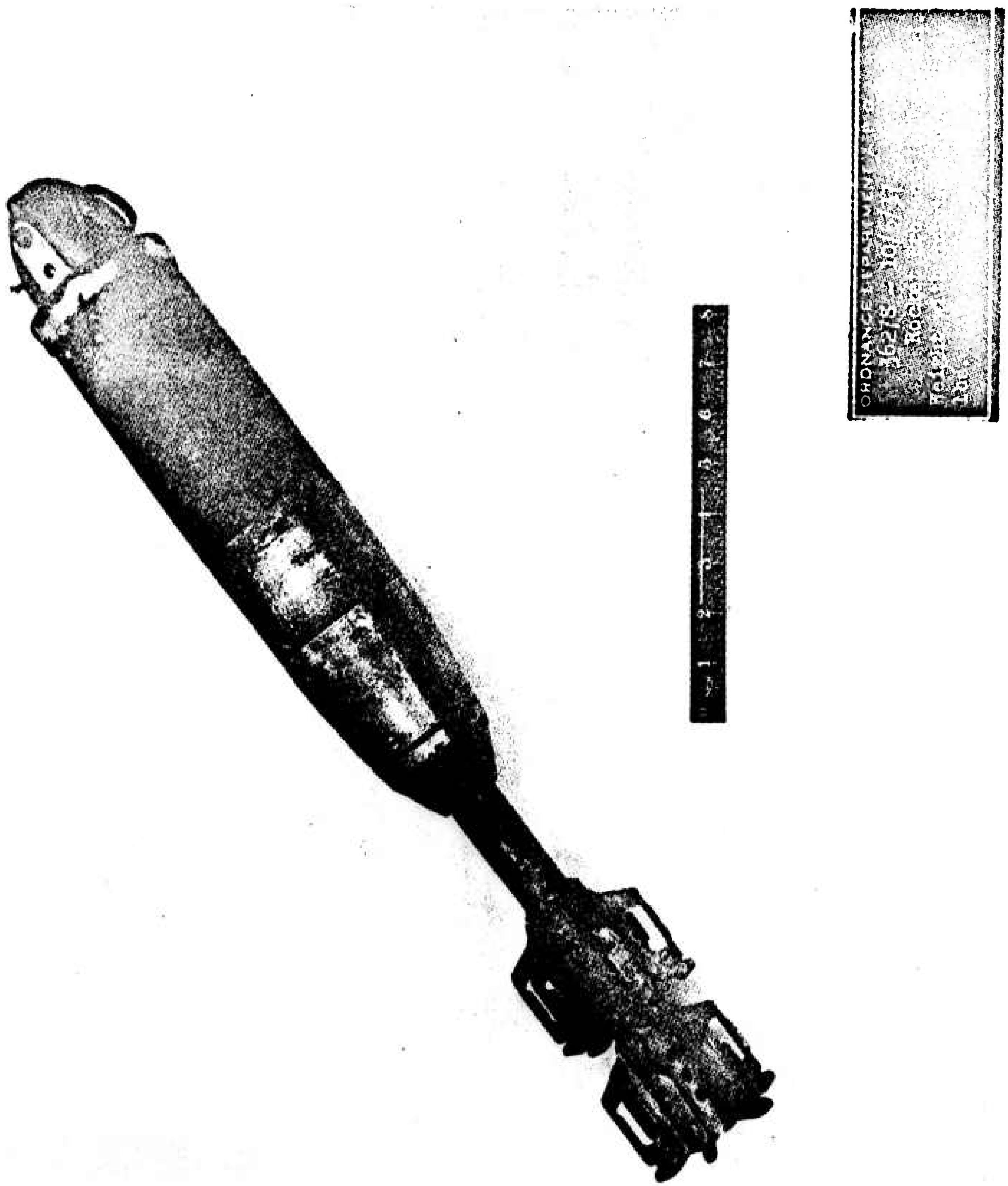
L. A. Skinner.
L. A. SKINNER,
Capt., Ord. Dept.

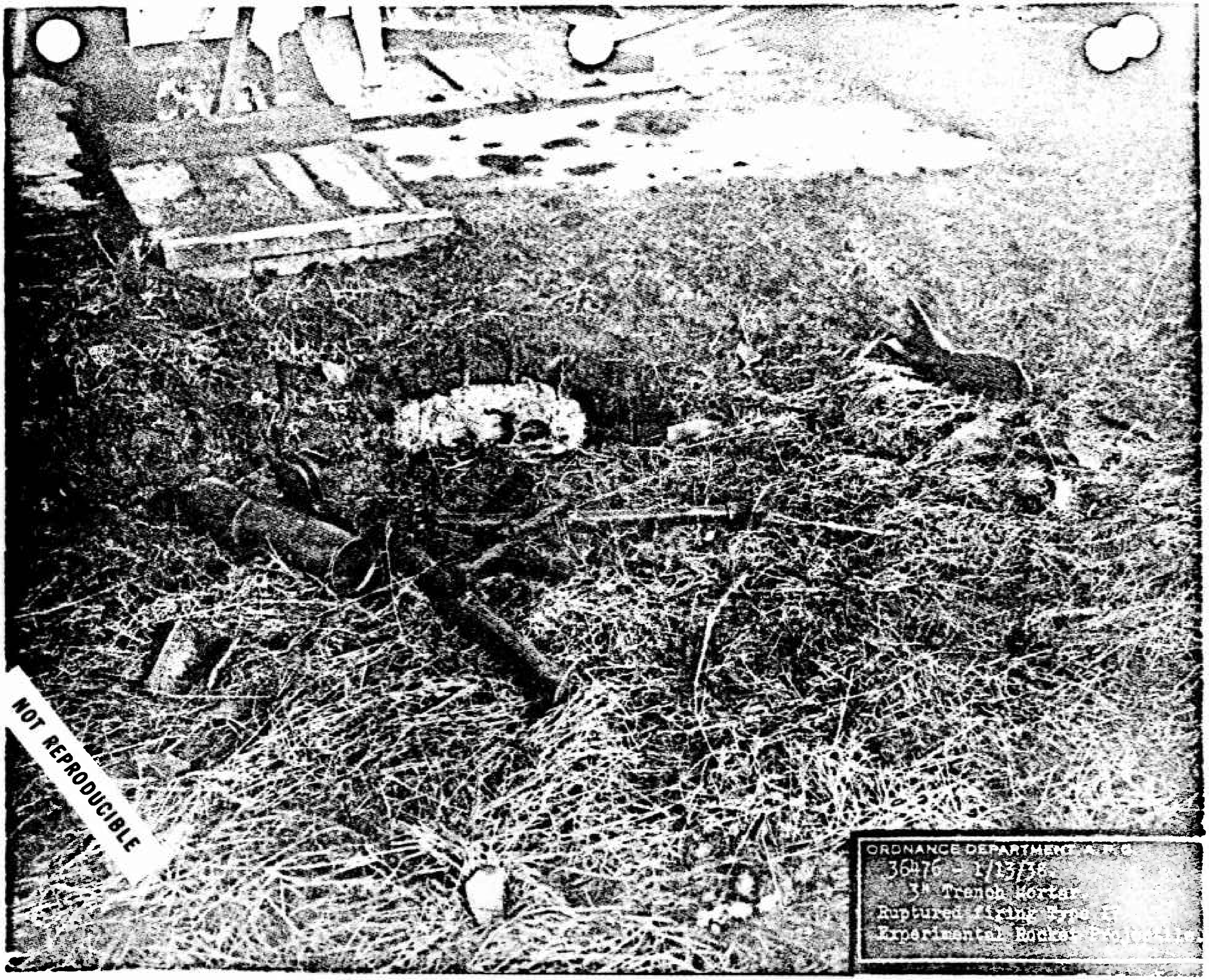
H. H. ZORNIG,
Lt. Colonel, Ord. Dept.,
Commanding.

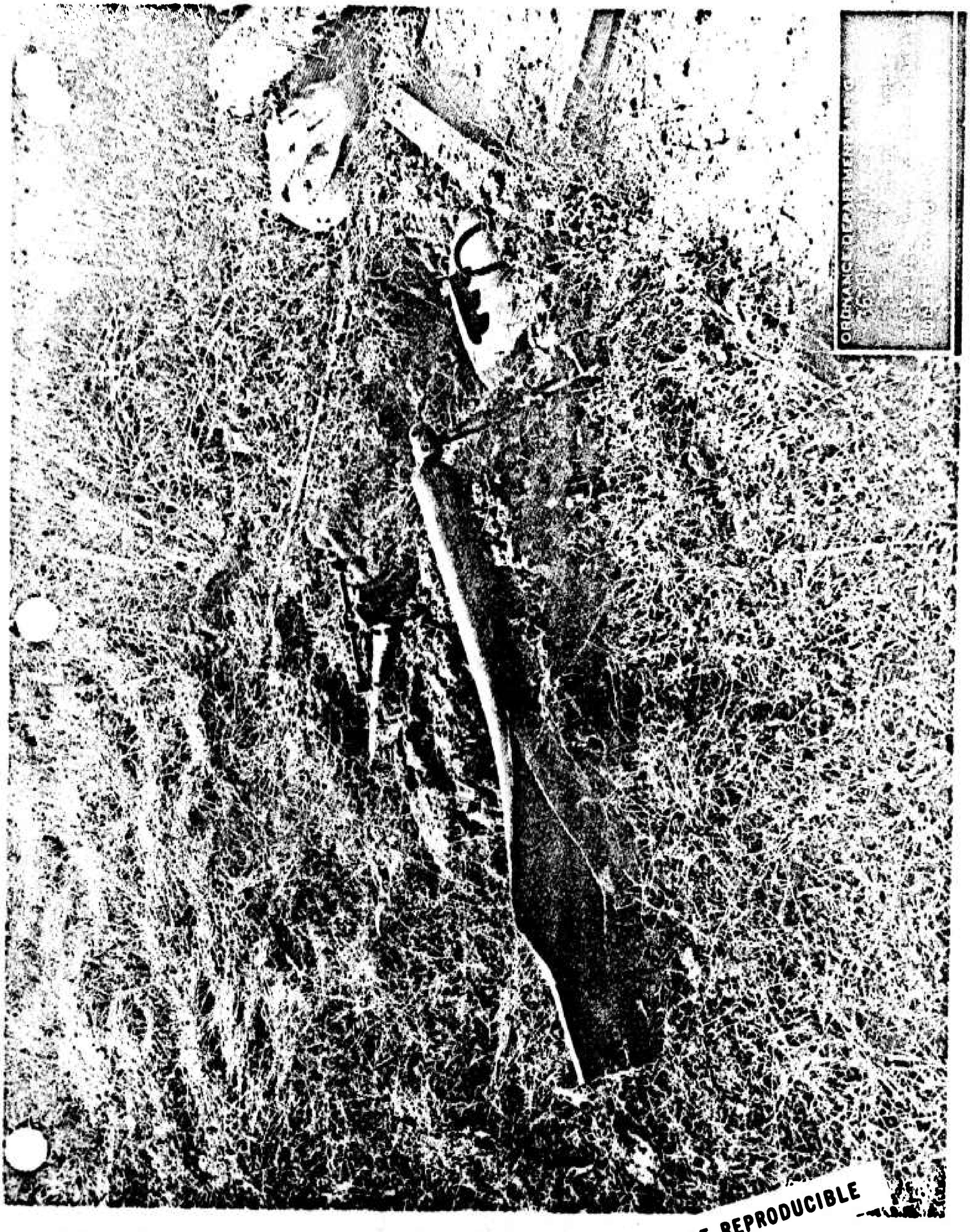









ORDNANCE DEPARTMENT
36476 - 1/13/38
3" Trench Mortar
NOT REPRODUCIBLE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